Dewar Configuration as an Approach to Maximizing the Cooling of Heat Loads in Two-Temperature Dewars

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Outline

Design Concept

- Goals
- What is a Dewar?
- Design parameters

Chosen configurations

Analysis

Proposed system for future research

Two-Temperature Dewar Design

Goals: Investigate 4K cooling Approaches for 100W and 3000W heat loads & Develop 4K(-452°F)/77K(-321°F) Dewar Design Concept

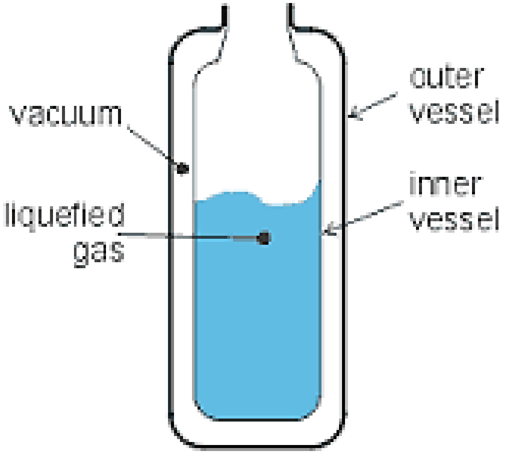
Note: Room temperature 293K(68°F)

Light bulbs 60 – 100W heat load

Electronic heaters can be 3000W

What is Dewar?

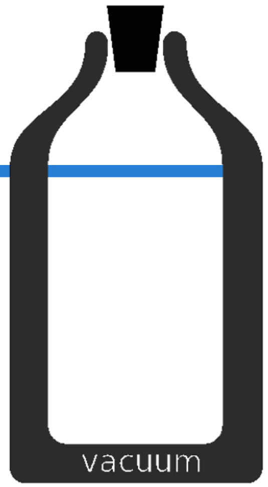
A vacuum flask or thermos: an insulating storage vessel that lengthens the time over which its contents remain hotter or cooler than the flask's surroundings



Dewar vessel

- Two flasks, placed one within the other and joined at the neck (closure)
- The gap between the two flasks is partially evacuated of air, creating a near-vacuum that can prevent heat transfer between the inside and outside of the system

Dewar Parameters



Look at the effects of the configuration on the system

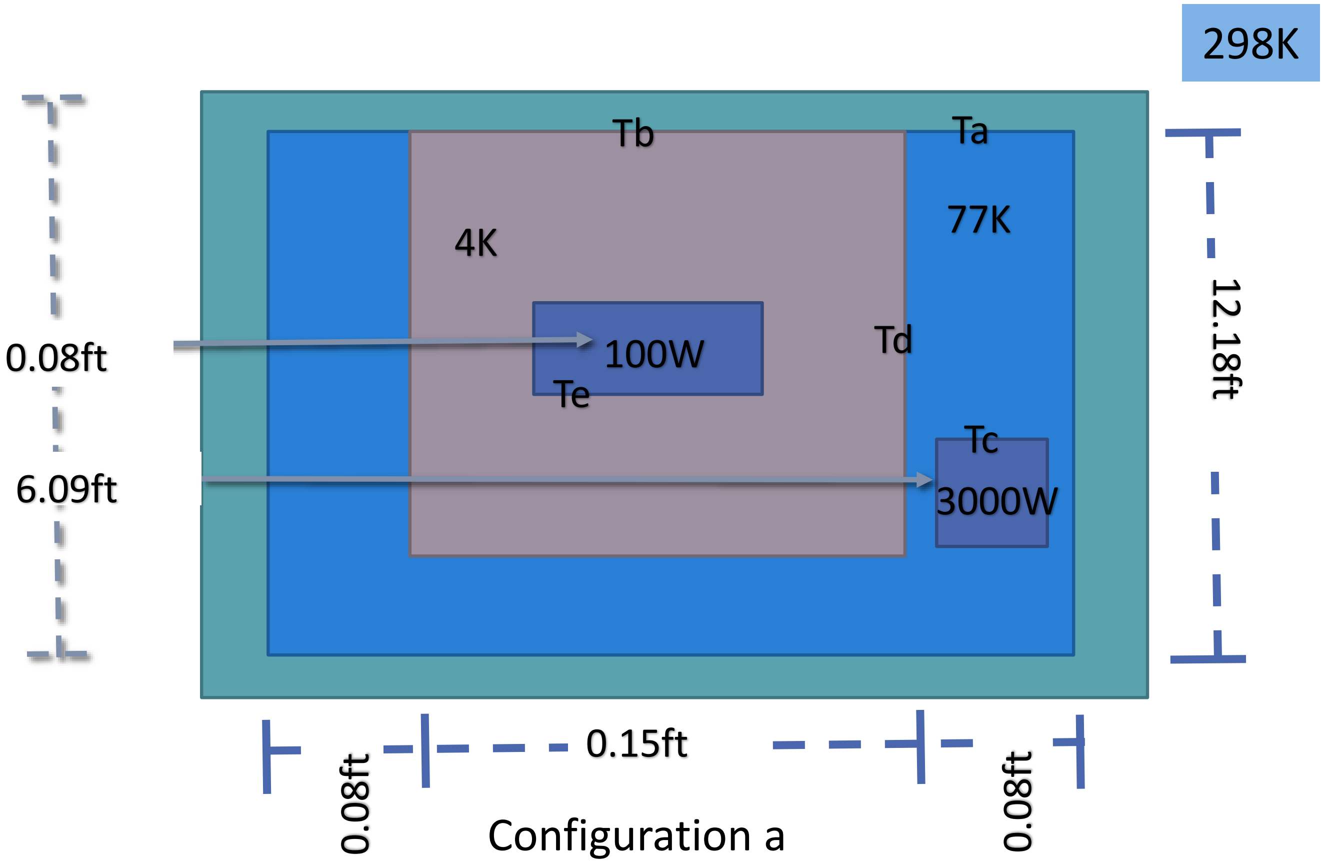
- Conduction heat transfer

Add insulation to said configuration

Considerations

- Restricted the space 1 cubic space for 4K and 1 cubic space for 77K
- The location of the heat load
- If the heat load is immersed in a fluid (i.e. helium, hydrogen, air)
- Where the heat loads are with respect to one another
- Plain walls
- Dimensions of the system

Dewar Configuration “a”

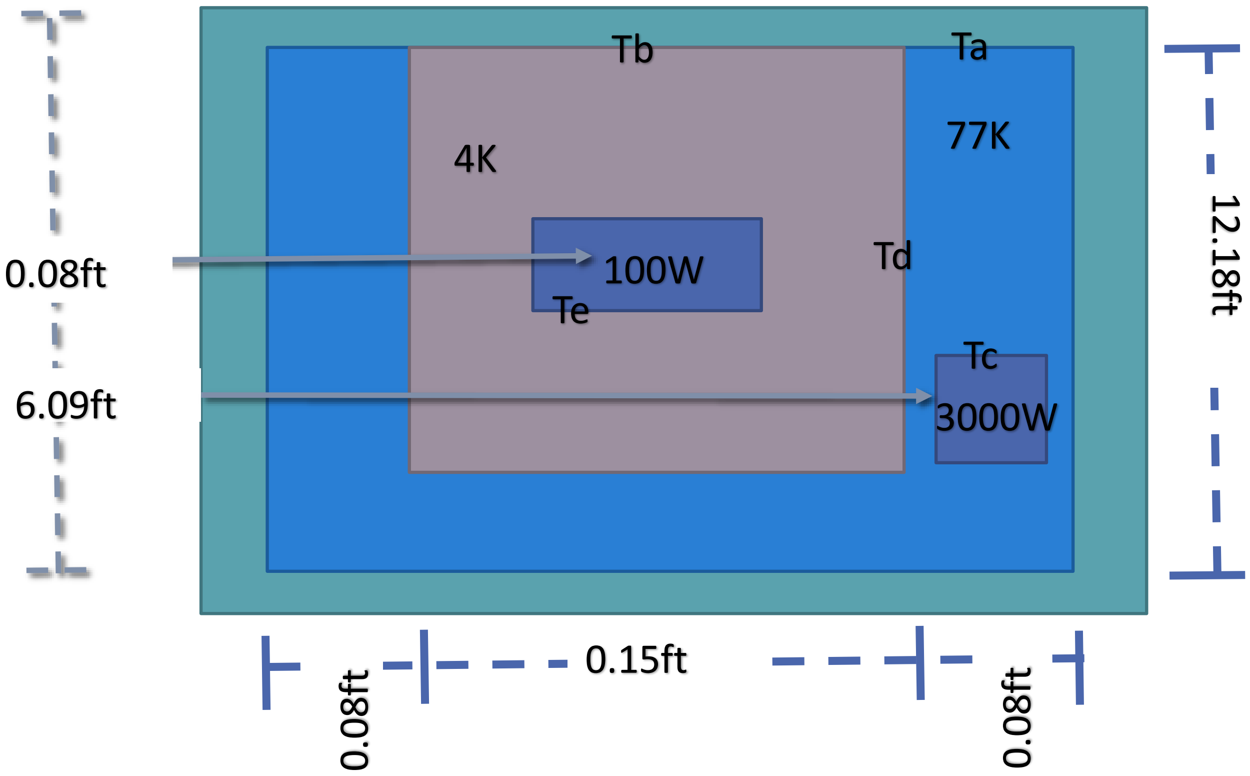


Configuration a

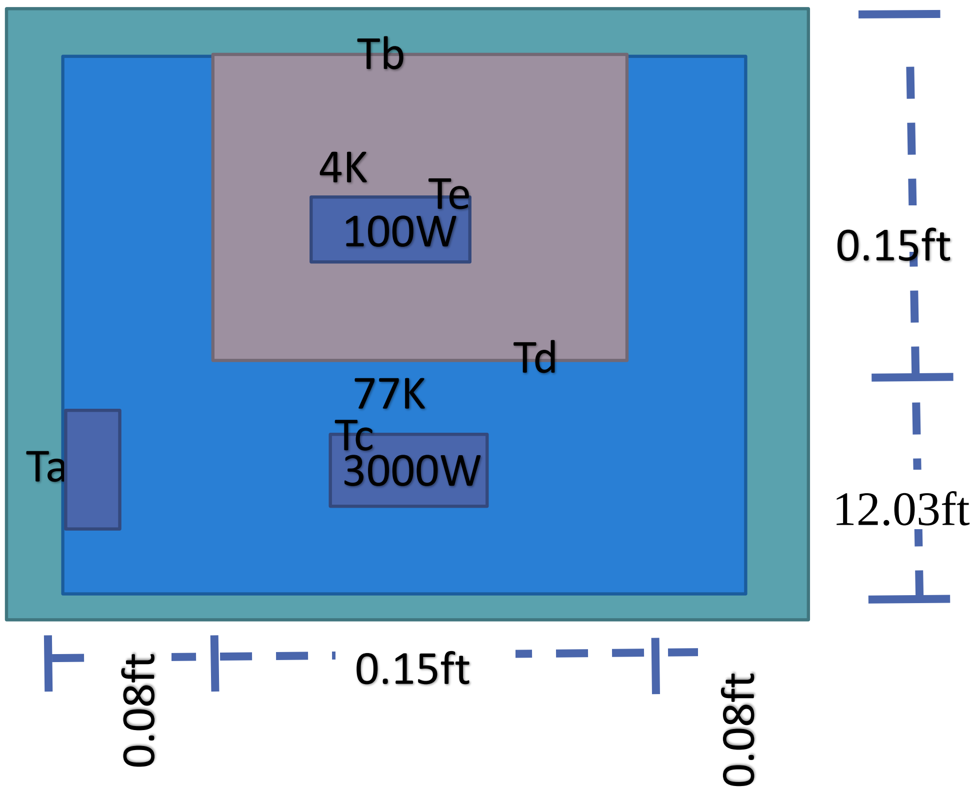
Where temperature change occurs

- *Ta – (298K -77K)*
- *Tb – (298K - 4K)*
- *Tc – (3000W-77K)*
- *Td – (77K-4K)*
- *Te – (100W-4K)*
- *Tf- (3000W- 100W)*
- *Tg – (3000W-4K)*
- *Th –(100W-77K)*
- *Ti – (100W-298K)*
- *Tj – (3000W-298K)*

Dewar Configurations “a” and “b”

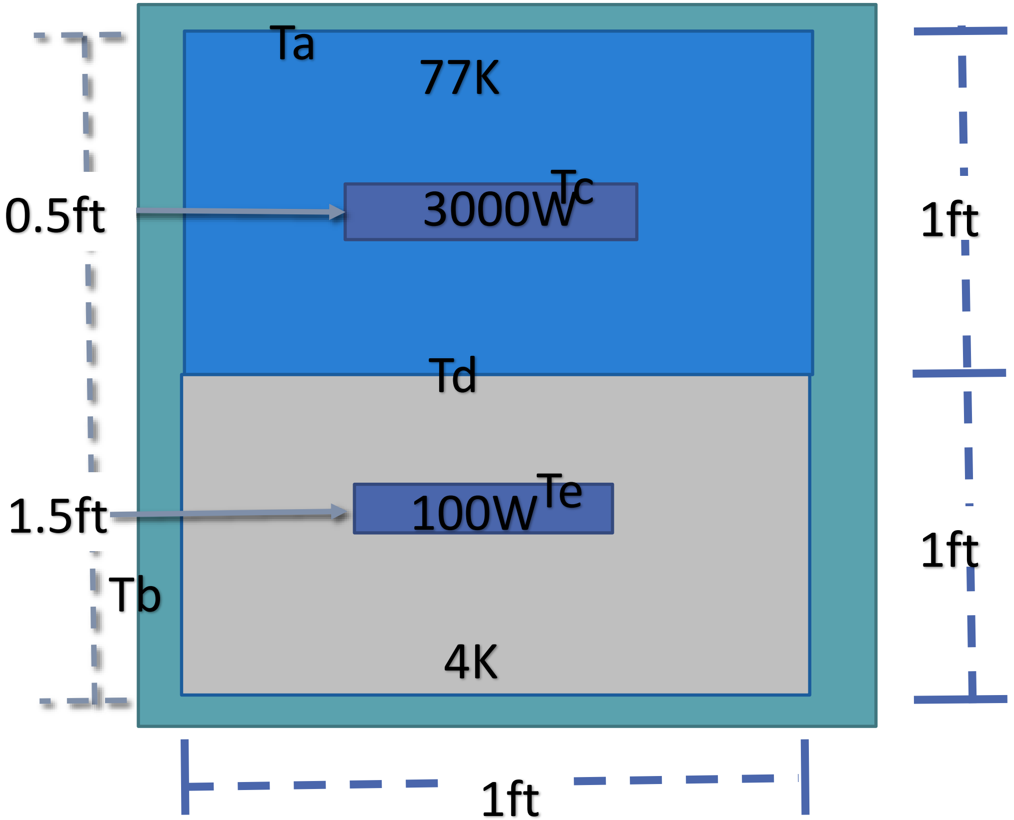


Configuration a

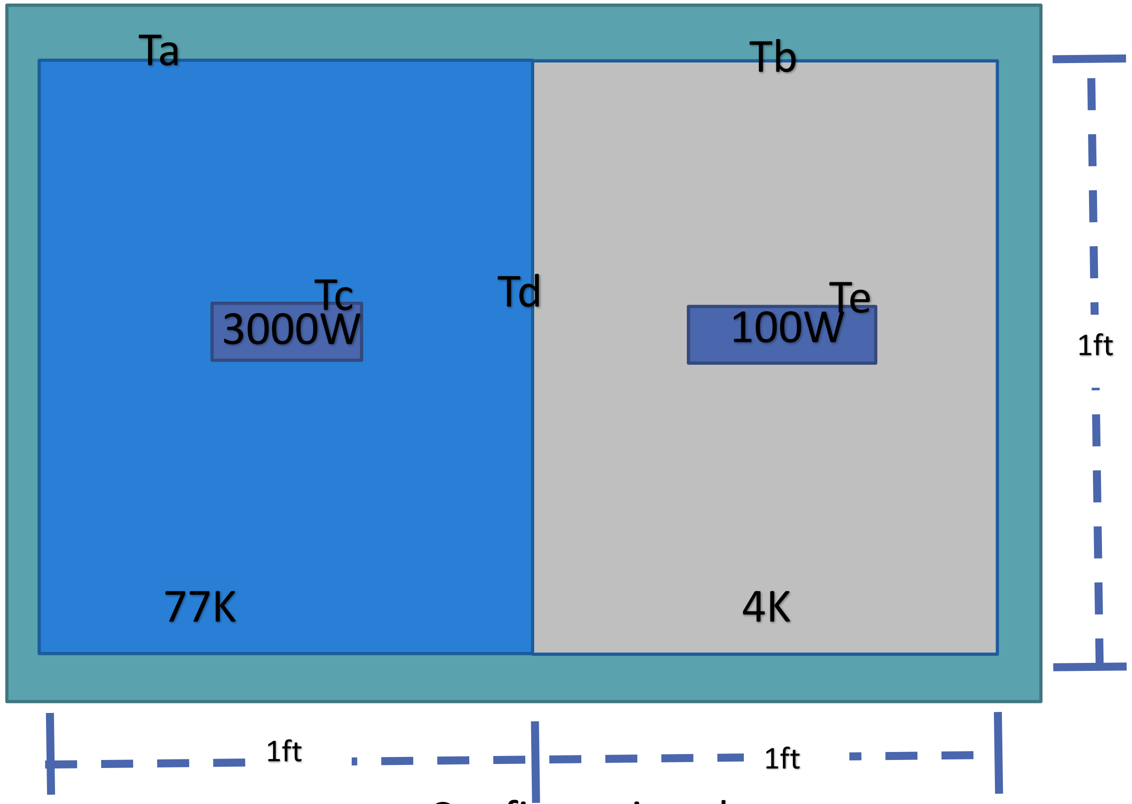


Configuration b

Dewar Configurations “c” and “d”

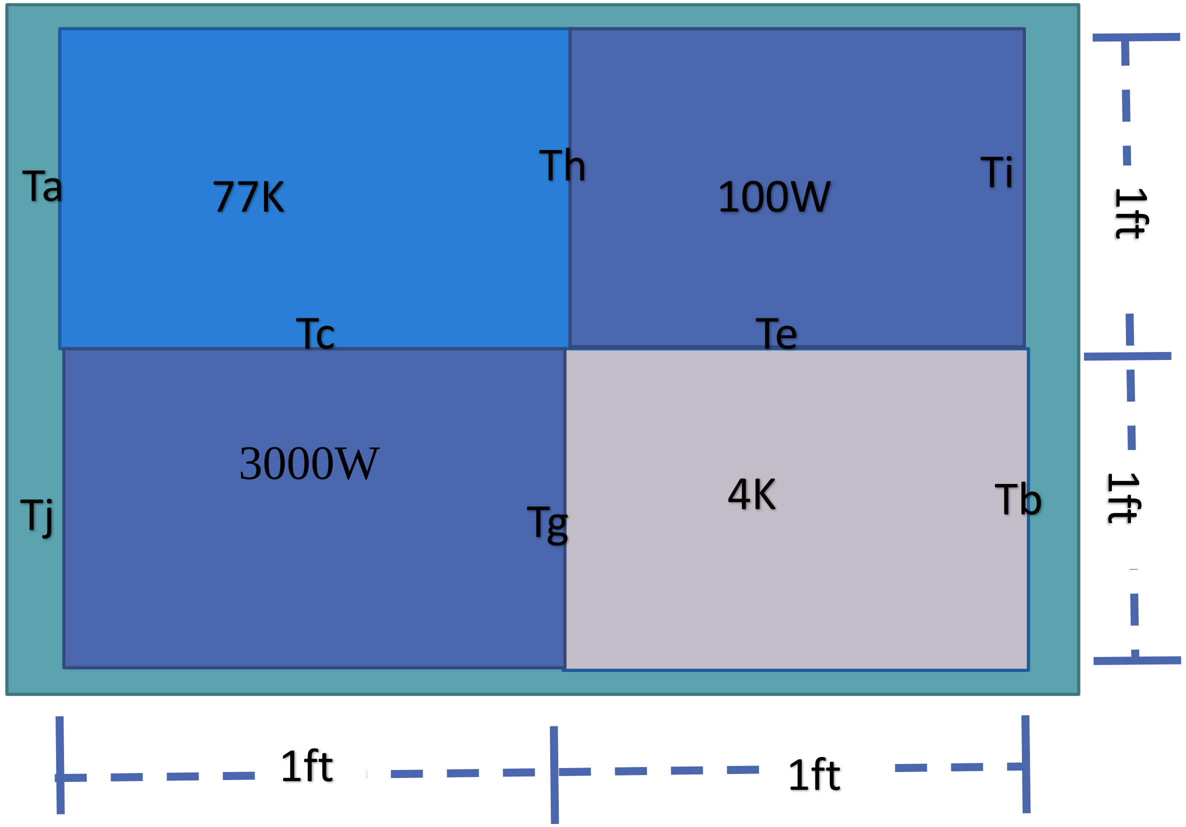


Configuration c

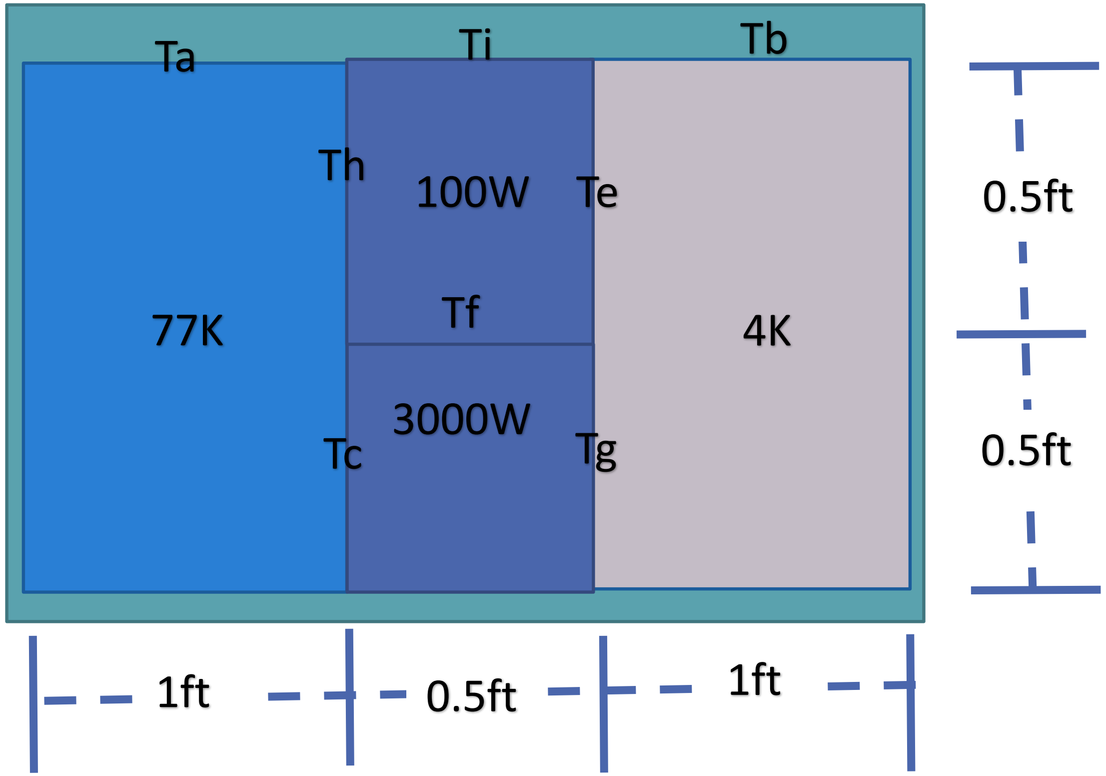


Configuration d

Dewar Configurations “e” and “f”



Configuration e

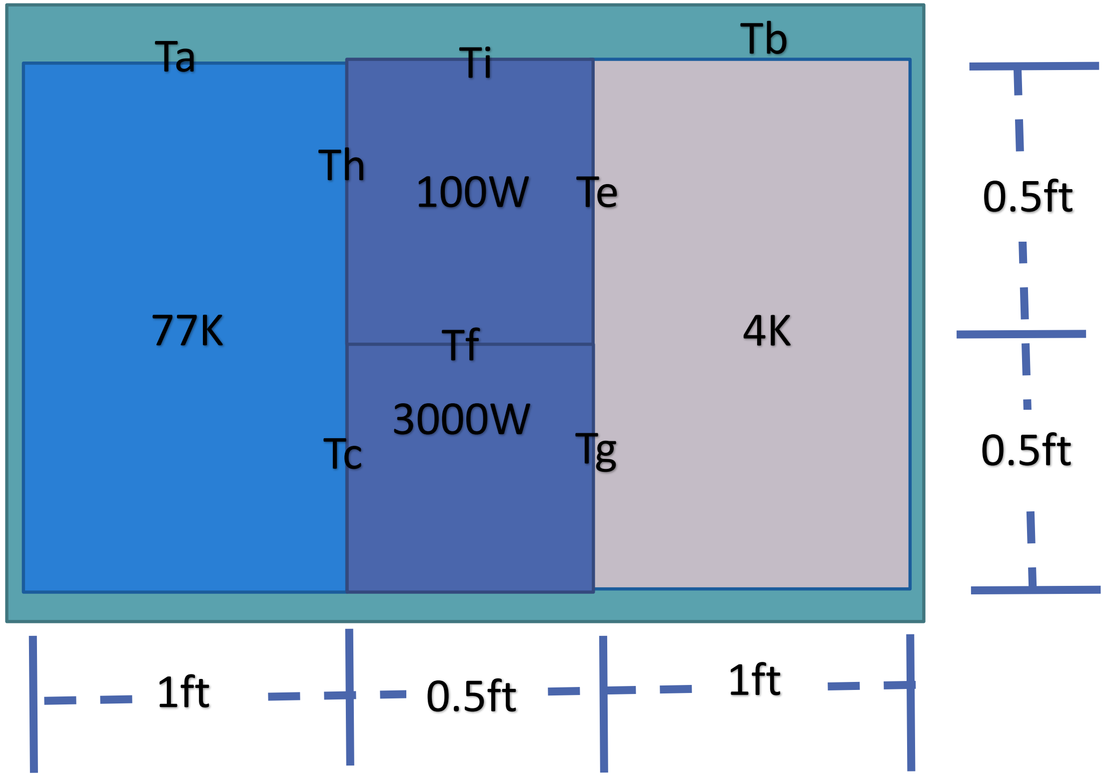


Configuration f

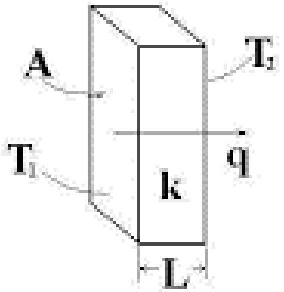
Analysis

Considered the

- Total system heat transfer
- Plain wall material
- Layers/type of insulation
- Changing the room temperature
- Varying the temperature of Helium



Heat Transfer Calculation



$$q = \frac{C_s(\bar{N})^{2.56} T_m}{N_S + 1}(T_H - T_c) + \frac{C_r \in_{RT}}{N_S}(T_H^{\ 4.67} - T_C^{\ 4.67})$$

General $q = k A \frac{T_1 - T_2}{L}$

- A = Area of the plain wall
- q = Heat transfer coefficient
- k = Thermal conductivity
- T2 = Warmer of the two temperatures
- T1 = Colder of the two temperatures
- L = Depth of the wall

Lockheed Martin-preconditioned [1]

- Nbar = layers/mm
- Ns = Number of Shields
- Th = T2, Tc = T1
- Cs = $8.95*10^{-8}$; and Cr = $5.39*10^{-10}$; Constants that describe thermal performance
- Etr = 0.031; Room temperature emissivity
- Tm = (Th-Tc)/2; Mean insulation temperature, K

Varying Outside Temp/Plain Wall Material

Resulting total system heat flow with system variations

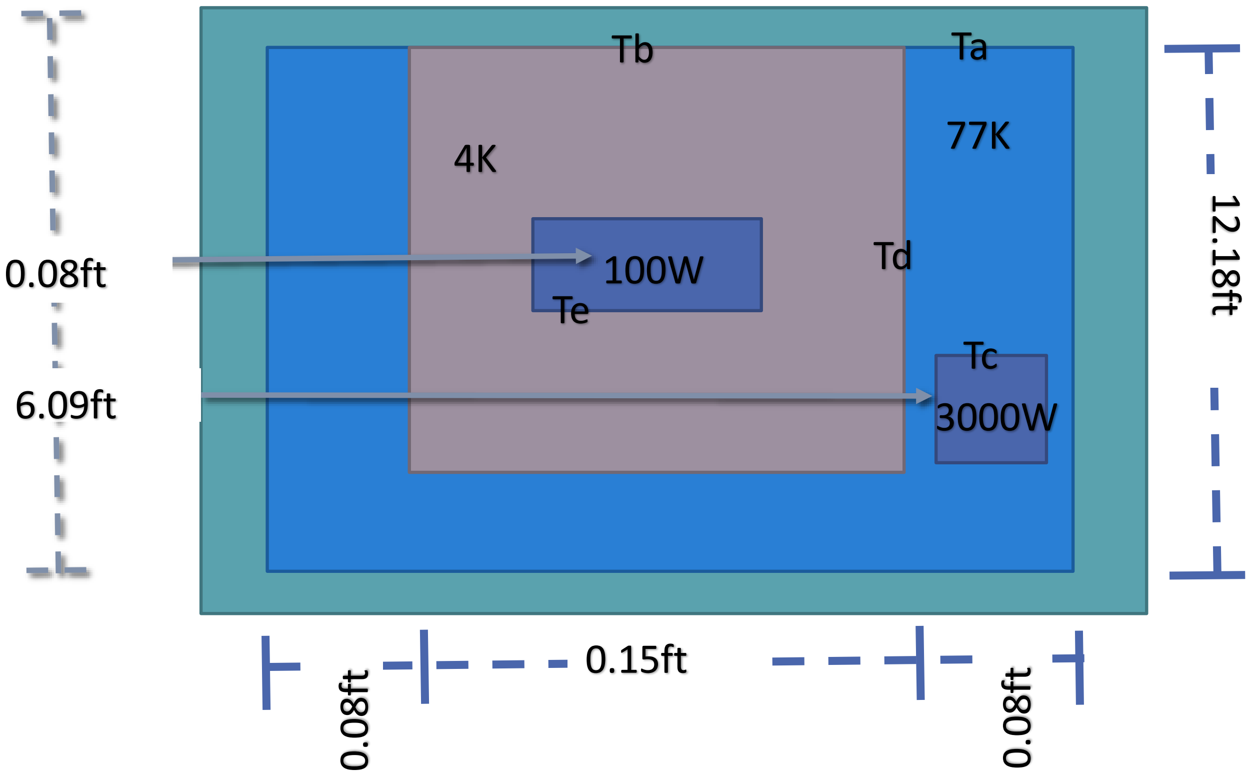
- Varied room temperature (e.g. 298 – 70K)
- Looked at plain wall (e.g. silver – graphene)

Variables			
Thermal Conductivity (W/m.C)	k_PW	410	410
	k_air	4000	0.024
Temp (K)	Outside	70	298
	He	4.2	4.2
	H2	77	77
Heat Flow (KW)			
Configuration	a	24	30
	b	45	57
	c	369	381
	d	369	381
	e	3	191260
	f	2	532

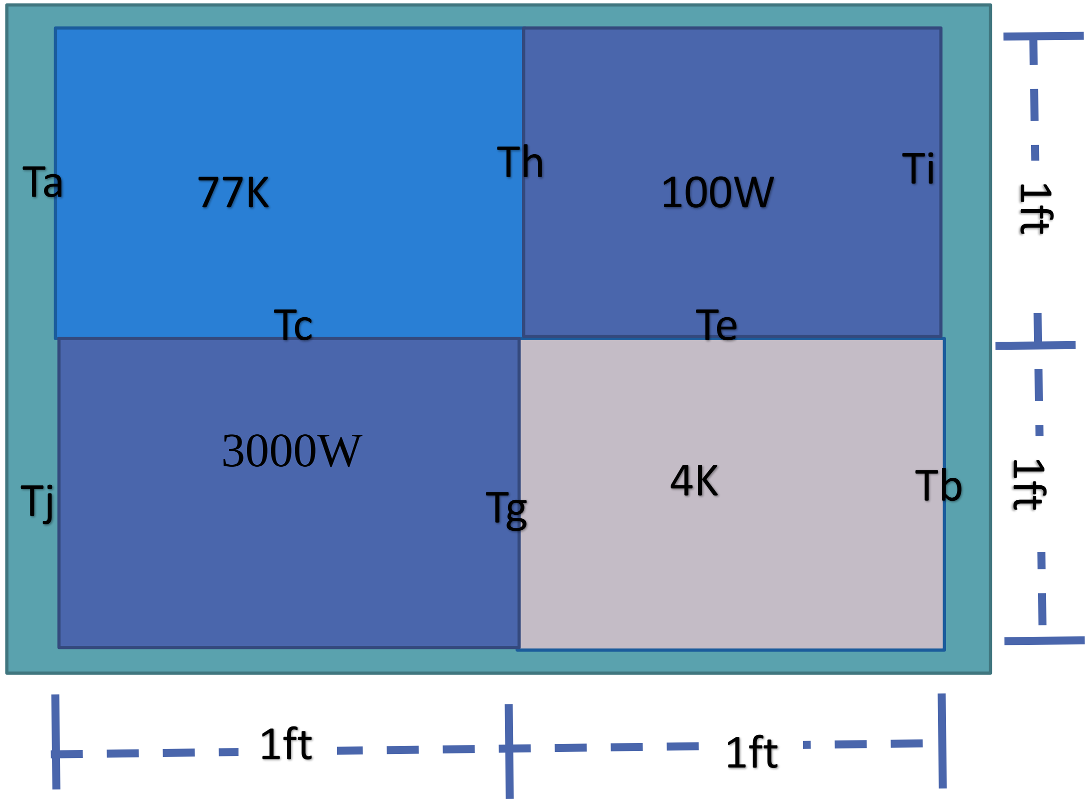
Just silver between air and the plain wall

Lowered outside temperature, graphene between silver and plain wall

Dewar Configurations “a” and “e”

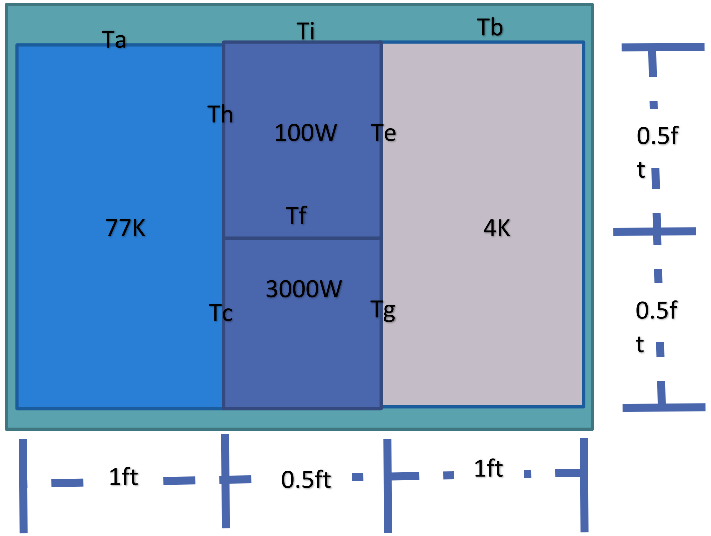


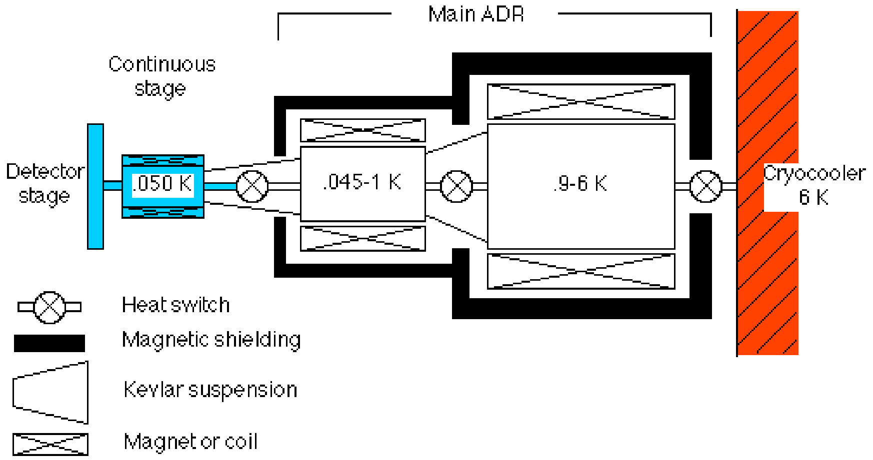
Configuration a



Configuration e

Proposed Dewar: Configuration f





- Substitute Helium (4K) with a multistage Adiabatic Demagnetization Refrigerator
- Spherical shaped system, operate entirely by conduction and utilizes graphene to insulate the walls on the inside of the system and multilayer insulation on the outside of the system

References

[1]Thermal Performance of Multilayer Insulations prepared for the National Aeronautics and Space Administration by Lockheed Missiles & Space Company Inc., 5 April 1974

[2]J. P. Holman, “Heat Transfer” , McGraw-Hill Higher Education, 9th edition, 2002

[3] USPAS Short course Boston, MA 6/14 to 6/18/2010

[4] U.S. Bureau of Labor Statistics (2014, November 28). Average Energy Prices, Washington-Baltimore - October 2014. www.bls.gov/regions/mid-atlantic/news-release/AverageEnergyPrices_WashingtonDC.htm

[5] Sherrer, D., Rollin, J., Patent US08814601. N.d. Print., (2014, August 26), patentimages.storage.googleapis.com/US8814601B1/US08814601-20140826-D00002.png

[6] Measuring Thermal Conductivity of Powder Insulation at Cryogenic Temperatures, Matthew Nicklas Barrios, Florida State University

[7] Reisch, Marc, Volume 91 Issue 5 | pp. 18-19, (2013, February 5, 2013). Coping With The Helium Shortage, cen.acs.org/articles/91/i5/Coping-Helium-Shortage.html?h=1429938890

[8] From Wikipedia, the free encyclopedia, *Hydrogen Economy*, (2014, December 17), en.wikipedia.org/wiki/Hydrogen economy

References

[9] NASA Goddard Space Flight Center, Cryogenics and Fluids Branch, (2004, September 15). The GSFC Advanced Adiabatic Demagnetization Refrigerator (AADR): A Development Project to Produce a Long Holdtime, Staged ADR, Cooled by a Mechanical Cooler), istd.gsfc.nasa.gov/cryo/ADR/adv_ADR/adv_ADR.html

[10] Weisend, J., (2011, September 23) Adiabatic Demagnetization Refrigeration, www.cryogenicsociety.org/resources/defining_cryogenics/adiabatic_demagnetization_refrigeration/

[11] Nast, T., Frank, D., Burns, K., Cryogenic Propellant Boil-Off Reduction Approaches, 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, 4 - 7 January 2011, Orlando, Florida

[12] Dr. Sarma V. Pisupati, S., (December 2014), EGEE 102: Energy Conservation and Environmental Protection Course, Mechanisms of Heat Loss or Transfer, www.e-education.psu.edu/egee102/node/2053

[13] Pop, E., Varshney, V., Roy, A., Thermal properties of graphene: Fundamentals and applications, MRS Bull. Volume 37, 1273 (2012)

[14] Godfrin, H., Cryogenic Fluids, European Advanced Cryogenics School, (2011), cryocourse2011.grenoble.cnrs.fr/IMG/file/Lectures/2011-Godfrin-Cryogenic_fluids-v2.pdf